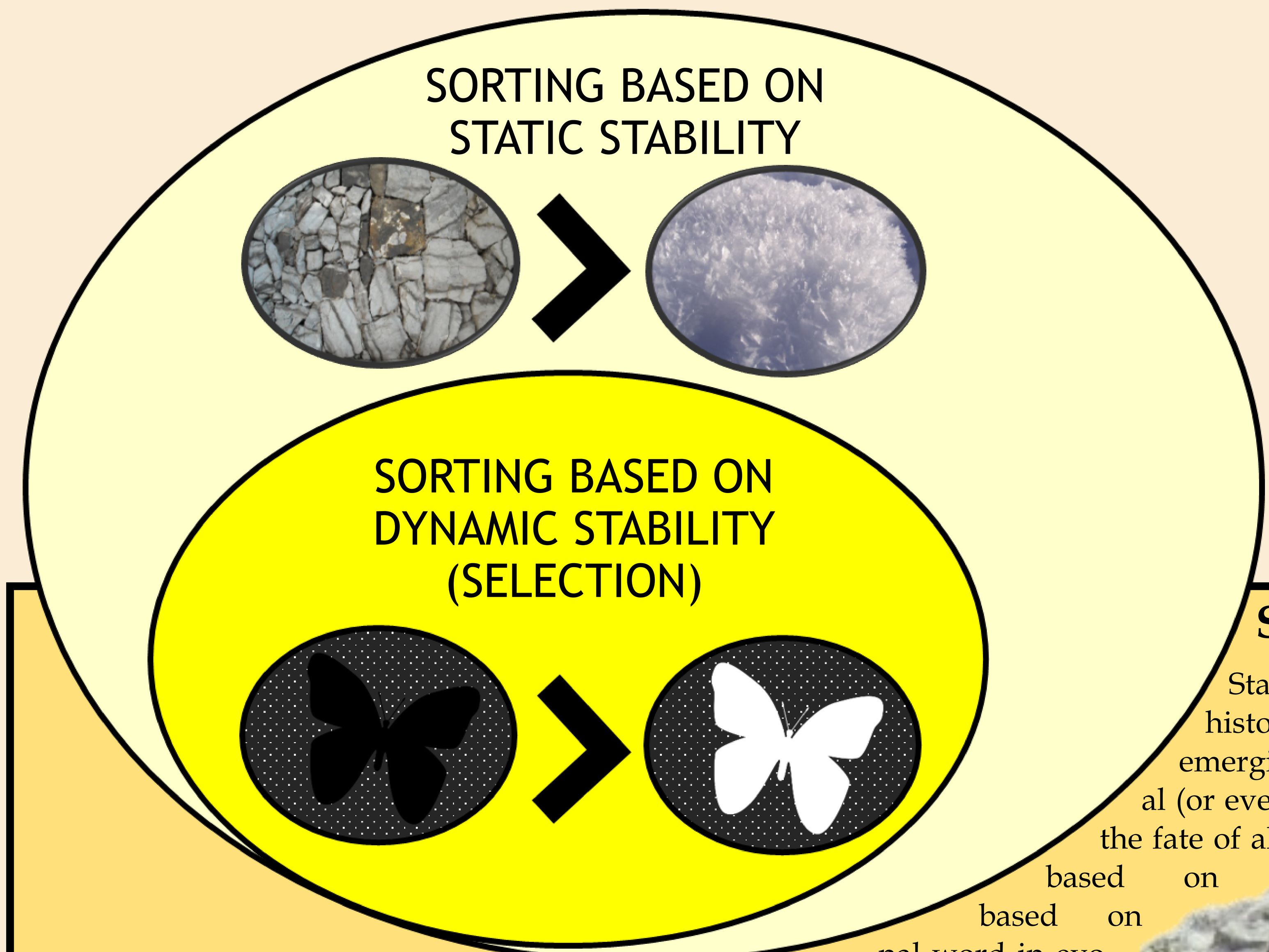
MACROEVOLUTIONARY FREEZING AND THE JANUSIAN NATURE OF EVOLVABILITY

Is the evolution (of profound biological novelty) **going to end?**



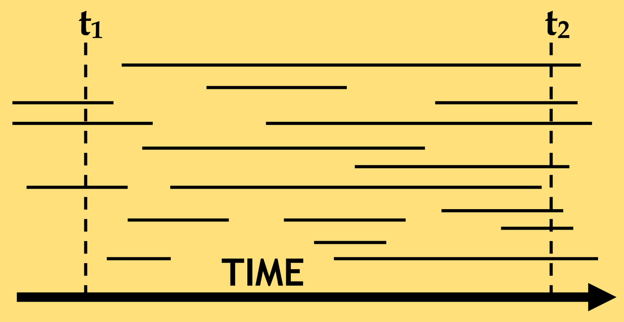
Introduction

The increasing maximal hierarchical complexity of organisms is one of the most prominent macroevolutionary trends. As was pointed out, e.g. by McShea (2015), this trend seems to be associated with several other macroevolutionary phenomena. The most notable are transitions to higher levels of organization, modular character of higher-level organisms, growth of variability among elements on the immediately lower level, and their gradual "machinification". Moreover, this trend seems to be typical for eukaryotes and it also gradually accelerates with a strong boost since Neoproterozoic-Cambrian period. In this poster, we report on our research on the possibility that this trend is tightly associated with another macroevolutionary phenomenon, the decreasing (macro)evolutionary potential of sexual clades, which manifests in their decreasing intraspecific and interspecific disparity.

> What is the cause of the trend of increasing hierarchical complexity?

> How is it related to other macroevolutionary phenomena?

Stability-based sorting (SBS)



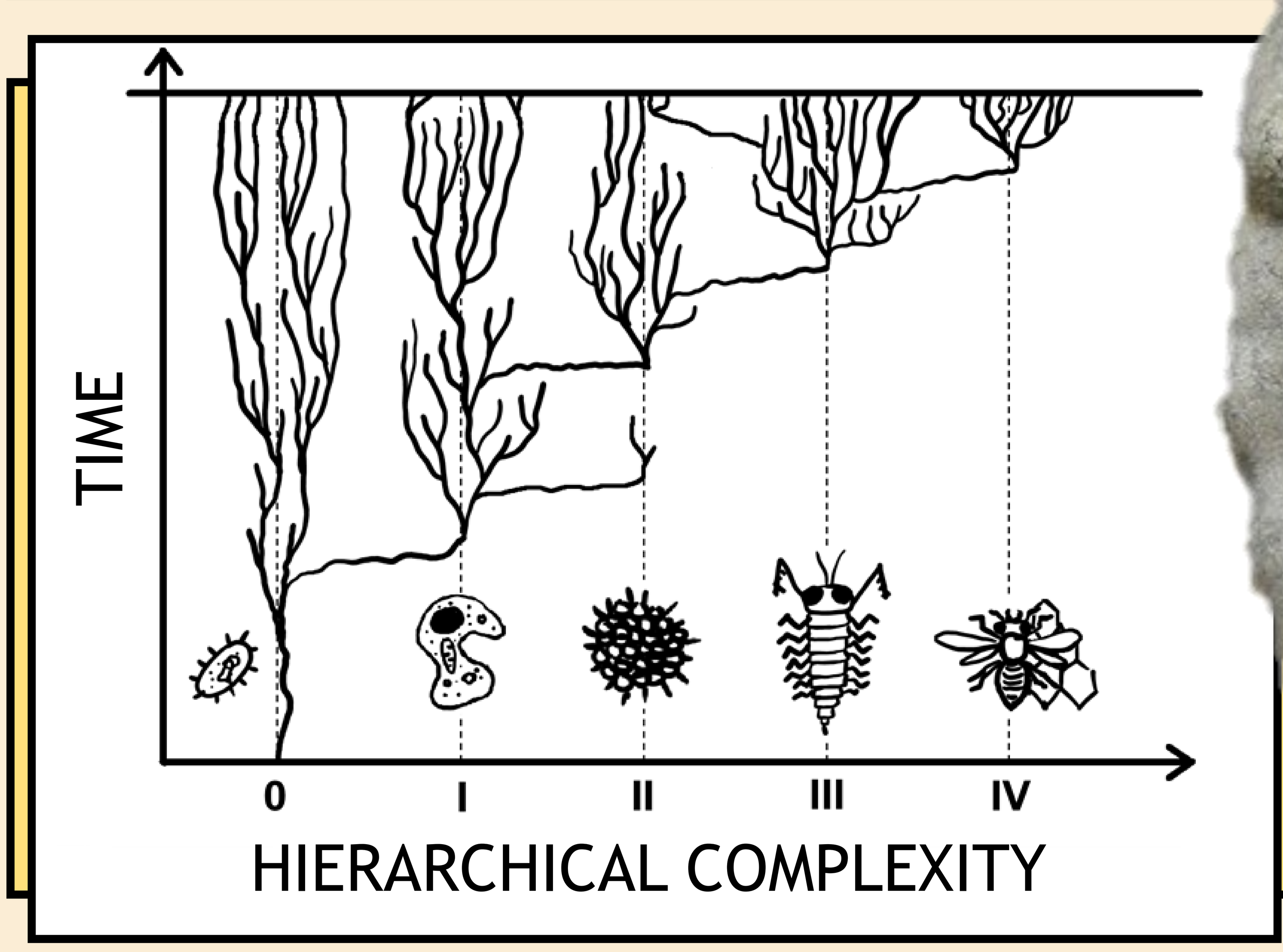
Stability-based sorting is a process common to all entities on all levels of all systems with history. It is based on the fact that changeable entities change, whereas stable or rapidly emerging entities accumulate and predominate in the system (t_2 in the right figure). Rather trivial (or even tautological) on the first sight, it is in fact a general process that ultimately determines the fate of all evolving systems. We showed (Toman & Flegr 2017) that natural selection (i.e. sorting based on dynamic stability) is a special case of SBS in its strict sense (i.e. sorting based on static stability), that SBS is much less opportunistic than selection and that it always has the final word in evolution. SBS offers a new explanation for numerous evolutionary phenomena. **Maybe the most important implication of SBS in biological systems is the effectively irreversible accumulation of further unchangeable elements of genetic architecture. Various characters exhibit various degrees of evolvability, i.e. the ability to adaptively change under appropriate selective pressures. Traits that are able to change easily and distinctly under proper selective pressures appear and disappear, whereas stable traits persist and accumulate in the taxon.**

Bright side of the evolution of evolvability

- > Evolutionary lineages are sorted based on their ability to generate adaptive novelties, which leads to the optimization of their genotype-phenotype map.
- > The structure of a genome evolves to reflect effectively the structure of a phenotype and the environment with all its selective pressures.
- > This increases the odds that the eventual changes in the genome will be adaptive and reduces the odds of them being maladaptive or lethal. It also reduces the number of mutations necessary to produce an adaptive phenotype.
- > The same process leads to the establishment of constraints that canalise the degree and character of subsequent evolutionary changes.
- > Nowadays, however, it is usual to think of the evolution of evolvability as a creative force, a source of robusticity and a necessary condition of further evolution of complex organisms.

Dark side of the evolution of evolvability

- > It follows from the SBS and the frozen evolution theory (see Toman & Flegr 2018) that more stable elements of genetic architecture with limited evolvability will accumulate during the existence of evolutionary lineages.
- > Lineages with genetic architectures that confer higher evolvability are initially sorted out. Effectively unchangeable genes are usually structured into quasiindependent modules.
- > SBS continues even on the higher level. More and more traits, modules and their groups irreversibly "freeze" by means of this sorting.
- > This leads to decrease of intraspecific and interspecific disparity and (macro)evolutionary potential of the lineage, i.e. the probability of producing major evolutionary innovations. **The end of (innovative) evolution?**
- > Asexual organisms, in which each individual establishes its own evolutionary lineage, may avoid this decrease thanks to species selection.



WARNING: THEORETICAL RESEARCH

Trend of increasing hierarchical complexity

- > "Frozen" lineages may reach a new advantageous combination of frozen elements; frozen genes, traits, or modules may "thaw". However, it is rare.
- > The only way to completely restore (macro)evolutionary potential is through **a transition to a hierarchically higher level of organization** by **internal modularization**, or **fraternal and egalitarian transition in individuality**.
- > SBS that leads to macroevolutionary freezing acts even on the new, hierarchically higher, level. As the subunits specialize, their diversity grows and modular character fades, their integration increases and further unchangeable connections accumulate. The whole system macroevolutionary freezes again and the only way out becomes **transition to even higher level of organization.**
- > This may repeat many times (see the left figure), resulting in the McShea's (2015) evolutionary syndrome. Significant acceleration of the trend since the Neoproterozoic-Cambrian might be associated with the origin of sexual eukaryotes and their complex multicellular representatives. Does growing organismal complexity continuously accelerate the trend?

Future directions

- > Testing the assumptions of frozen evolution theory (i.e. the existence and basis of particular evolutionary trends)
- > Comparing the dynamics of evolution in sexual and asexual lineages
- > Virtual simulation of open-ended evolution including the factor of (macro)evolutionary freezing
- > Analogies with other evolving systems, e.g. cultural evolution
- > Astrobiological implications

Conclusions

The trend of increasing hierarchical complexity and associated phenomena such as the diversification of elements on the immediately lower level of organization, their "machinification", typicality of the trend for eukaryotes (and especially their complex representatives) and its acceleration with a strong boost since the Neoproterozoic-Cambrian period can be explained by the increasing pressure of species selection, which results from **SBS-mediated decrease of (macro)evolutionary potential on every hierarchical level in sexual organisms.**

author of the photography: Sailko

References

McShea, D. (2015). Three Trends in the History of Life: An Evolutionary Syndrome. *Evolutionary Biology*, 43, 531–542.

Toman, J., & Flegr, J. (2017). Stability-based sorting: The forgotten process behind (not only) biological evolution. *Journal of Theoretical Biology*, 435, 29-41.

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